

The most amazing greening on Earth

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by Patrick J. Michaels

We've long been fond of showing the satellite evidence for planetary greening caused by increasing carbon dioxide, particularly the work of [Zhu et al.](#)(2016):

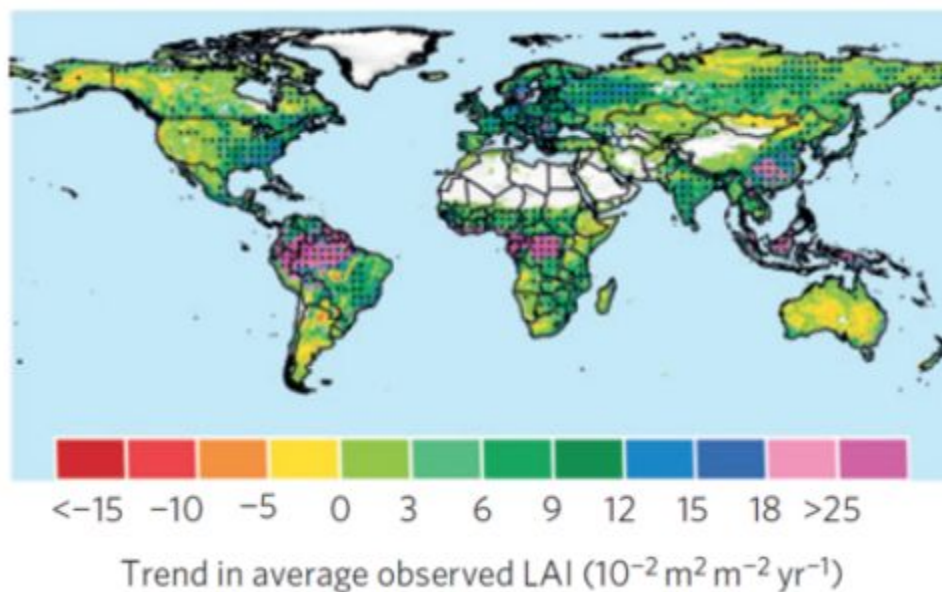


Figure 1: Trends in Leaf Area Index around the planet. Note the units are in hundredths (10^{-2}) of meters per square meter. An increase of 25 (Purple, right end of scale) is actually an annual change of .025 square meters per year. Note that the largest greenings are in fact over the South American, African, and Australasian tropical rainforests.

The variable usually shown is the Leaf Area Index (LAI), an interesting measure of vegetation density. A value of 1.00 means that one square meter of the sensed vegetation, if the leaves were spread out, would entirely cover a square meter.

Plants with exceedingly dense vegetation (think of your over-fertilized tomato plants by the end of summer) have LAI values far in excess of 1.0, and some, such as sparse grasslands, may be quite a bit less than 1.0, indicating the presence of a lot of bare ground.

A new [paper](#) by Simon Munier, of France's [Centre National de Recherches Météorologiques](#), and several co-authors, segregates satellite-sensed LAI data into different vegetation types, taken over the period 1999-2015. This allows the researchers to quantitatively determine the amount of greening that is taking place over time, depending upon the vegetation type.

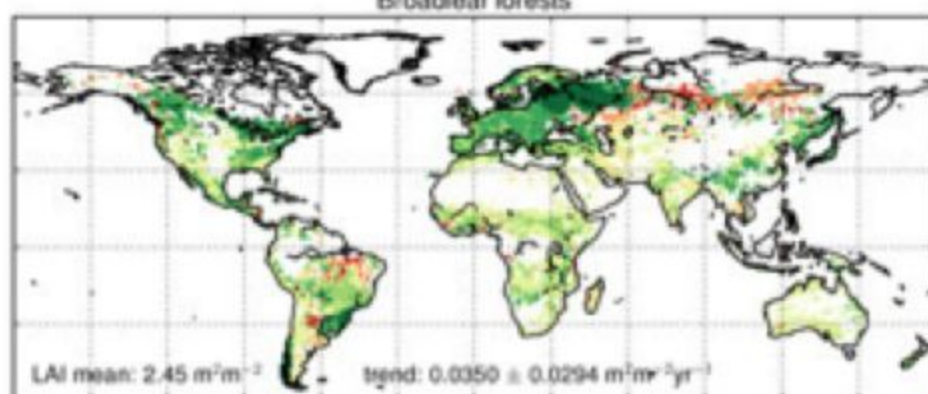
A note on LAI: when applied to crop plants, it doesn't necessarily directly correlate to the yield or productivity of the plant. Think about those over-fertilized tomatoes again. Gardeners often complain that they have huge vegetation masses (i.e. large LAI's) but few fruit. However, if the vegetation in question is in fact consumed entirely as an agricultural product (think lettuce, for example) the LAI in fact is a direct measure of agricultural productivity.

The most common vegetation type on earth—grassland—is often agricultural in usage. Many are either directly grazed, or, as is the case for the most productive ones, harvested for hay which is then consumed when pasture is no longer growing enough to support cattle or sheep. Rapidly increasing grassland LAI values are therefore a very useful greening of the earth.

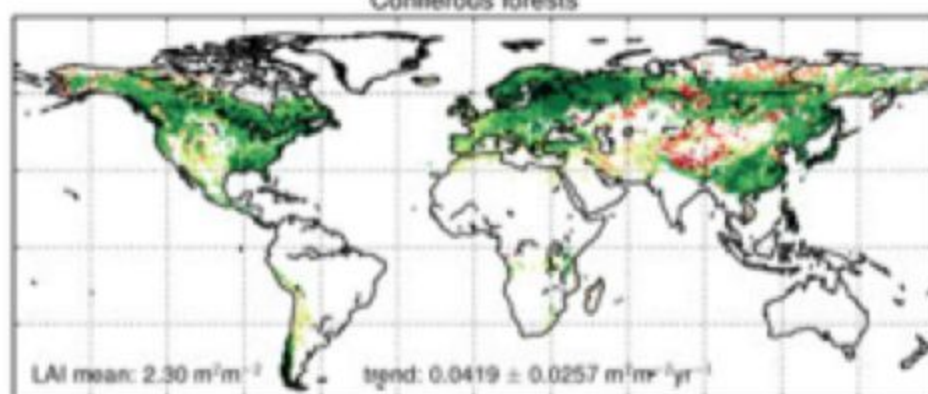
Munier's team divided the satellite data into that sensing broadleaf (deciduous) forests, evergreen forest types, summer and winter crops, and grasslands. Their 17-year time series provides average LAI values as well as temporal trends.

The cool part of the paper is its Figure 8, showing mean and trend values worldwide for the LAI in six vegetation types:

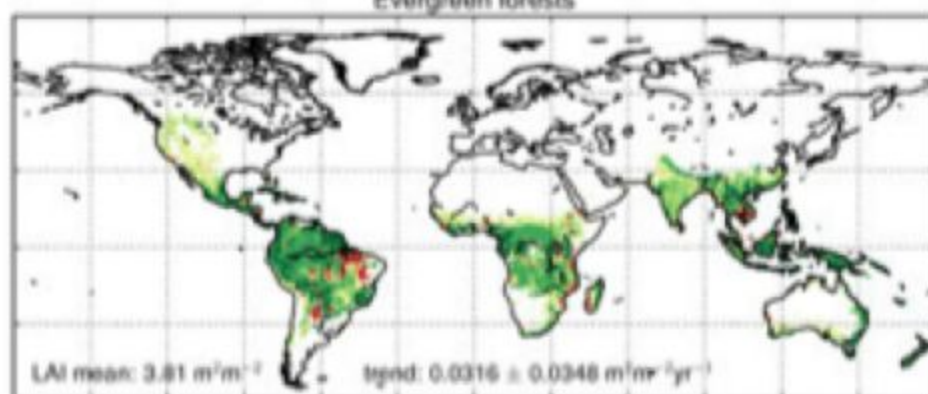
Broadleaf forests



Coniferous forests



Evergreen forests



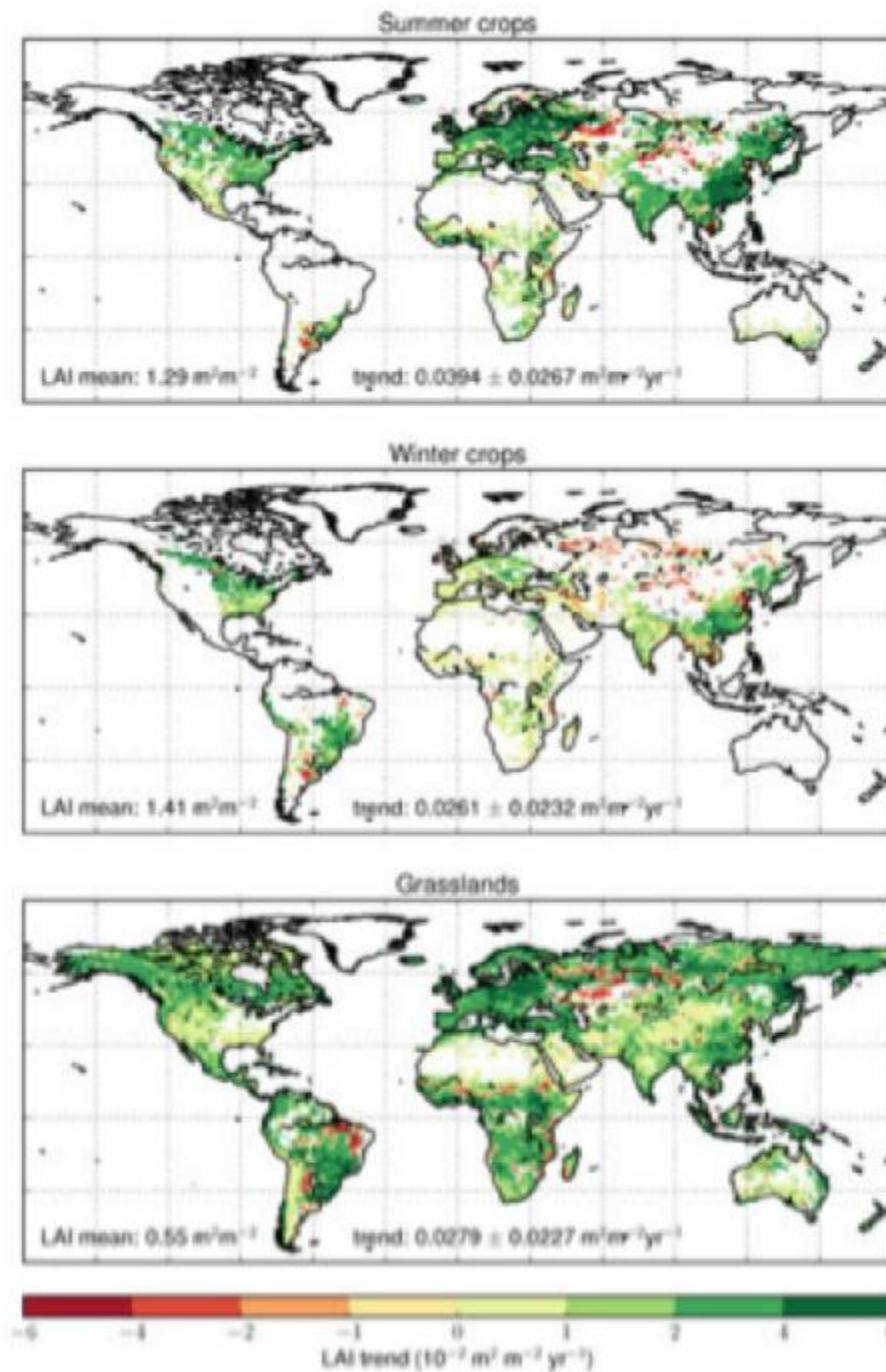


Figure 2:

Average LAI value for the six vegetation types (given quantitatively in the lower left corner of each map) and the trend in LAI per year, on the right. The +/- is the spatial standard deviation, which is generally large because soil, terrain, and weather difference clearly influence LAI and vegetation health. Nonetheless, all the trend values are significant at the $p\text{-value} < .01$. These seemingly arcane figures reveal a spectacular greening of the world's grasslands. See text for details.

The details are in the numbers. The average (1999-2015) grassland LAI is 0.55, meaning its ground cover worldwide averages less than complete. The trend, of 0.0279 square meters per year, is a remarkable 5.0% per year. Over the 17-year period of record, this means that grassland LAI increased by 85%. According to Munier et al., grassland, as the most common vegetation type, covers 31% of the global continental surface measured (Antarctica was not sampled). This is a remarkable greening.

The aforementioned Zhu et al. study performed a factor analysis to determine the causes. According to the paper,

Factorial simulations with multiple global ecosystem models suggest that CO₂ fertilization effects explain 70% of the observed greening trend, followed by nitrogen deposition (9%), climate change (8%) and land cover change (LCC) (4%). CO₂ fertilization effects explain most of the greening trends in the tropics, whereas climate change resulted in greening of the high latitudes and the Tibetan Plateau.

In other words, 78 [70 + 8] percent of observed planetary greening is caused by carbon dioxide and its effect upon climate.

We have repeatedly demonstrated (within [here](#), for example) that about a half of a degree (C) of observed planetary warming is ascribable to anthropogenerated changes in the atmosphere. The main result appears to be a planet that is becoming so much greener that it is readily apparent from space.